



Figure 9. Ectomycorrhizal mantel hyphae, x400.

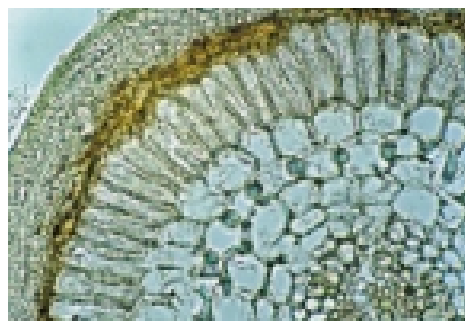


Figure 10. Mantel mycorrhiza and interior Hartig net between cortical cells, x1000.

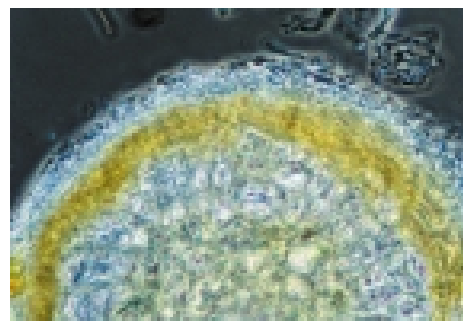


Figure 11. Ectomycorrhizal root xsect., x250.

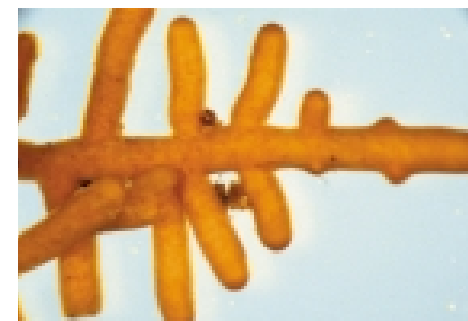


Figure 12. Birch root ectomycorrhizal with pinnate branching habit.

from the nutrient poor soils. In addition, the glove-like covering of mycelium provides physical protection for the delicate root tips and also a barrier to the entry of soil microorganisms (Figure 11). The mycelium produces antimicrobial compounds that deter competition from other fungi and

microbes. In return, the spruce roots provide a supply of essential sugars and amino acids that are necessary for growth of the fungal mycelium and production of fungal fruiting bodies, the mushrooms.

It is possible that the present northern limit of spruce is at higher latitudes than

would otherwise be possible because of the presence of mycorrhizal symbioses and, conversely, these fungi would not be present without their host trees. Even broad-leaved birches are not immune from this dependency (Figure 12).

The diversity of these fungal-root associations provides a multitude of plants with a range of strategies for functioning efficiently under seemingly adverse conditions. It has been estimated that around 95% of all plant species characteristically form one of several types of mycorrhizal associations. Significant amounts of organic carbon may also be transferred between different plants through interconnecting fungal mycelia, thereby reducing competition for available resources and maintaining community diversity.

Parasitic Fungi— Where the Broom Rust Fits In

Parasitic fungi, and especially the spruce broom rust (*Chrysomyxa arctostaphyli*, Figure 13), occur abundantly in the boreal forests of Interior Alaska, where the geographic ranges of spruce and kinnikinnick or mealberry (*Arctostaphylos uva-ursi* var.

uva-ursi), acting as an intermediate host in one stage of the life of the broom rust, coincide. Germinating rust spores on the spruce result in a perennial systemic infection on the host tree. The rust fungus produces auxins (plant growth hormones) that stimulate prolific branching on the spruce at the site of infection, causing the familiar “witch’s broom” (Figure 14). Other parts of the host tree continue to grow normally. Fruiting of the rust fungus occurs on the needles of the witch’s broom, causing the telltale rusty-orange coloration. In the fall, needles of infected branches are shed and the broom then appears as a mass of dead twigs (Figure 15).

Northern flying squirrels and red squirrels take advantage of these dense and often massive branch clumps. Squirrels hollow out brooms, construct nest sites (Fig. 16 a & b.), raise their young, and then cache dried epigeous and hypogeous fungal fruit bodies (Figs. 17a & b.) in these old nest sites that serve as winter food larders (Phillips 1998).

Left behind by these sciurid and microtine rodents and insects are feces and frass that contain viable but dormant fungal spores. During the following spring,



Figure 13. Left: *Chrysomyxa arctostaphyli* broom at treetop.

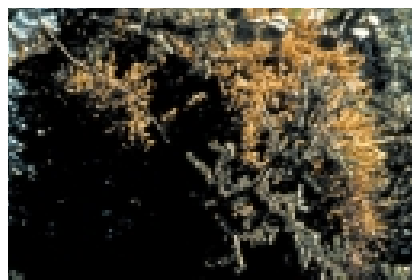


Figure 14. Top-right: *Chrysomyxa arctostaphyli* broom with fruiting rust.

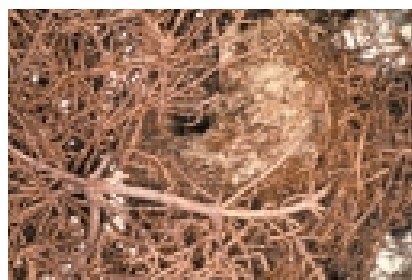


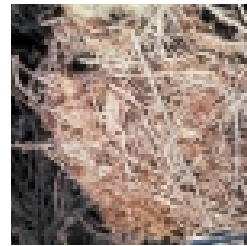
Figure 15. Bottom-right: Broom and potential nest/cache site with copious branching.

spores germinate and produce new hyphal growth that becomes associated with the rootlets of young plants, once again creating the beneficial mycorrhizal associations. Each summer and fall a new crop of fungal fruiting bodies appear, ready to be harvested by the mycophagous mammals and insects that are attracted to the nutrient rich spores.

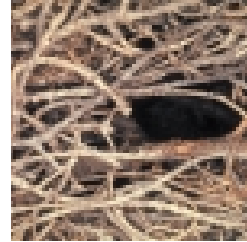
Closing the Cycle

So it is that the forest cycle begins anew. Seedling establishment requires the development of a mycorrhizal association for the efficient extraction of moisture and soil nutrients. The fungal root mantle provides a protective physical barrier and microbial defense mechanism for the young and tender roots in a soil that will become, if not already, nutrient poor, yet able to sustain tree growth for 150 to 250 years or more. Soil and litter buildup ensures sufficient organic detritus to harbor the many non-mycorrhizal fungi that break down organic matter and release the otherwise bound nutrients to the soil. The litter also provides shelter for small mammals and insects and a suitable bed for future fruitings of mycorrhizal species of fungi.

Fungi that are harvested, dried, and



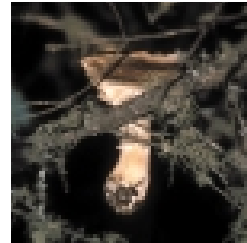
16a



16b



17a



17b

Figure 16a. Flying squirrel nest and cache site.

Figure 16b. Flying squirrel nest opening.

Figure 17a. Drying agarics (gilled mushroom) next to a flying squirrel.

Figure 17b. Drying *Lactarius* sp.

Figure 18a. Cone scale middens with surrounding *Hylocomium splendens* mosses.



18a

Photographs courtesy of Gary A. Laursen

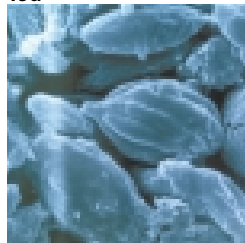


18b

Figure 18b. Cone scale middens with diggings for hypogeous truffle fungi.



19a



19b



20a



20b

Figure 19a. Fecal *Glomus* spores.

Figure 19b. Fecal *Elaphomyces muricatus*, *Gauteria* sp. and *Hysterangium separabile* spores.

Figure 20a. *Alpova diplophloeus* basidiome (fruitbody).

Figure 20b. *Gauteria otthii* basidiome (fruitbody-field).

stored in the tangled masses of branches of the witch's brooms are consumed throughout the winter months. The spores, after passing through the animals and being deposited in dung, will, in their turn, germinate and grow. Witch's brooms and cone scale middens (Figure 18) provide both nesting sites and caches for copious reserves of dried fungal fruiting bodies eaten during the long winter months. Fungal spores pass through the animals and are shed in the dung pellets where they are effectively wrapped in protective nutrient rich packets. As with some flowering plant seeds, passage through an animal not only disperses the seed (or fungal spores in this case), but the digestive chemicals of the animal also prepare the seed (or spore) for germination after defecation (Figure 19). Squirrels also search in middens for hypogeous false truffle fungi (Figure 20) and true truffle fungi (Figure 21).

With age, healthy trees gradually become stressed and, over a period of time, prone to increased attack from insect and fungal infections. With death, the trunks and branches are returned to the debris-choked forest floor to join a host of invertebrate animals and decomposer fungi, which slowly break down the plant cellulose and lignin by mechanical and chemical means, thus releasing nutrients to again be recycled into the ecosystem.

Fallen trees play a significant role on the debris-strewn forest floor by providing convenient raised walkways or highways for travel by smaller animals (Figure 1). These animals, in their turn, deposit spore-laden feces on the logs and upon the forest floor debris. Flying squirrels are particular-

ly important because they disperse mycorrhizal and other fungal spores in their dung pellets in the form of "nutrient pills" — rich in yeasts, nitrogen-fixing bacteria, and the vital nutrients necessary for germination, early growth, and establishment.

Waves of decomposer fungi, in a multitude of different shapes, sizes, and forms, soon become residents in the forest. Examples are the agarics (gilled), polypores (bracket and shelf fungi), tooth fungi, chanterelles, coral fungi, puffballs, and cup fungi. The above ground forms, such as the agarics *Amanita*, *Cortinarius*, *Lactarius*, *Pholiota*, and *Russula*, the boletes such as *Boletus*, *Fuscobolus*, *Leccinum*, and *Suillus*, and tooth fungi, such as *Hydnum* and *Sarcodon* species, are particularly abundant and striking on the forest floor. These above ground forms are accompanied by their below ground cousins such as the false truffles *Alpova* (Figure 20a), *Gauteria* (Figures 20b), and *Hysterangium* (Figures 20c and 20d), and the true truffle, *Elaphomyces* (Figure 21) and *Geopora* species. Their fruit bodies are harvested, dried, cached, and used for winter food by small mammals.

Conclusion

This complex cyclical biological system is dynamically balanced. Any change in the physical environment will be reflected in the biotic components of the ecosystem. Under the influence of global climate warming, hypothesized increases in microbial activity can only increase concerns for altering the arctic and subarctic carbon pool and contribute to an increase in the emission of greenhouse gases. Climate

Photographs courtesy of Gary A. Laursen

warming trends are having adverse effects by increasing plant stress through desiccation. Of concern is the possible decline or demise of the northern boreal spruce forest in the next 50 to 100 years, and what might replace these forests. Any changes in the forest structure will impact the ecosystem at all levels—the large megafauna, small mammals, invertebrates, microbes, trees, shrubs, herbs, bryophytes, lichens, and even microscopic soil algae.

Continued integrated research will assist in comprehending the effects of altering one aspect of these biotic cycles in the ecosystem.



Figure 20d. *Hysterangium separabile* fruitbodies.



Figure 20c. *Glaucomys sabrinus* with *Hysterangium separabile* fruitbody.



Figure 21. *Elaphomyces muricatus* cleistothecium (fruitbody), a true truffle with roots.

Photographs courtesy of Gary A. Laursen

Glossary

abiotic — pertaining to non-living conditions.

biotic — pertaining to life or specific life conditions.

boreal — northern.

ectomycorrhizal—describes when fungi associated with plant roots are external, not within the cell structure of the plant root.

hyphae — vegetative threadlike filaments, which form the mycelium and fruitbody of a fungus.

microtine — small rodents consisting of the lemmings, voles, and mice.

mushrooms — fruiting bodies of fungi that support sexual reproduction.

mycelium — the vegetative part of a fungus, consisting of a mass of branching filaments called hyphae.

mycophagous — mushroom eating.

mycorrhizal — the symbiotic association between fungal mycelium and plant roots.

mycoses — fungus infections.

sciurid — mid-sized rodents consisting of the squirrels.

taiga — intermediate zone between the boreal forest and tundra.

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National Park Service photograph

Ancient Hunters of the Western Brooks Range: Integrating Research and Cultural Resource Management

By Jeff Rasic

“Look at this one!” “Hey, here’s another over here!” “This one is huge...and almost complete!” In the first ten minutes at the Caribou Crossing site—a barren, remote hilltop in northwestern Alaska surrounded by rocky peaks and hundreds of miles from the nearest road or village—the crew of eight archeologists found almost 30 large, masterfully made stone spear points. We suspected they were 10,000-11,000 years old. Even the old sourdoughs on the crew had given in to the excitement and were scurrying around like kids hunting for Easter eggs. And for good reason; rarely does an entire field season encompassing dozens of sites yield so many stone tools, particularly tools this old. The vast majority of known sites in the region consist of a surface scatter, with perhaps five or ten pieces of stone flaking debris. The sites are often impossible to date, a guess of 200-12,000 years old is the most precise archeologists can be. Particularly rare are sites dated to the early end of this time range, and few sites anywhere in the Americas have yielded such a dense accumulation of

spear points.

In addition, we had been in a holding pattern for the first three days of the season, huddled in our tents waiting for the snow to melt from a July storm. The crew had just found a focus for their pent up enthusiasm. The systematic, painstaking, and sometimes tedious work of mapping and documenting the site could wait a few minutes while we enjoyed this amazing place. Despite the apparent chaos of archeologists running in all directions, the knoll quickly sprouted a forest of small pin flags, which marked the precise locations of artifacts and ensured each was returned to its original location. We would map these later and examine spatial patterns to reconstruct site activities and to establish the age of artifacts by associating them with any radiocarbon samples we might recover.

Holding these well-crafted tools in the hand, one could not help ponder some interesting questions. What animals were hunted using these massive points? Why were these painstakingly-made weapons thrown away with apparent carelessness and in such large numbers? Was the hilltop crowded with people all at once, or was

the accumulation the result of occasional stops by a few hunters over centuries? Were there similar sites on the numerous hilltops visible from this knoll?

But our purpose here was not to tally a high artifact count. Nor did we have a special interest in projectile points. Points, however, and lots of them, were what this site presented, and they were obviously vital to the story the site had to tell. Information from Caribou Crossing was also part of a larger, multi-year program aimed at understanding how the earliest hunter-gatherers in the region made a living. The research sought information on how people structured their seasonal movements across the landscape, how they procured food and other resources, and how they organized family or social groups.

One of the most fascinating problems in archeology is how humans initially settled the Americas at the end of the last ice age, sometime before 12,000 years ago. It is truly an impressive story as nearly all corners of the New World were settled in an archeological instant, perhaps in less than a thousand years. In the process, people encountered unfamiliar plants and

Test excavations underway at the Caribou Crossing site. A grid is projected onto the site to provide reference points for measuring artifact locations in three dimensional space. Sergei Slobodin, an archeologist from Magadan, Russia, and Sabra Gilbert-Young, a graduate student at Washington State University, take notes.

Left: Screening sediment to retrieve small artifacts at the Tuluaq Hill site. Wrench Creek and the De Long Mountains in the background.

National Park Service photograph

animals, a countryside largely devoid of other people, and all occurring in the face of drastic environmental changes as the climate shifted to one more like that of today's.

The adaptations of early Alaskans is of special interest in this story since most

archeologists agree that the first Americans originated in Asia and passed through Alaska. At some point, these people must have adapted to high latitude living, with its extreme seasonality, rapid fluctuations in food availability, and harsh temperatures.

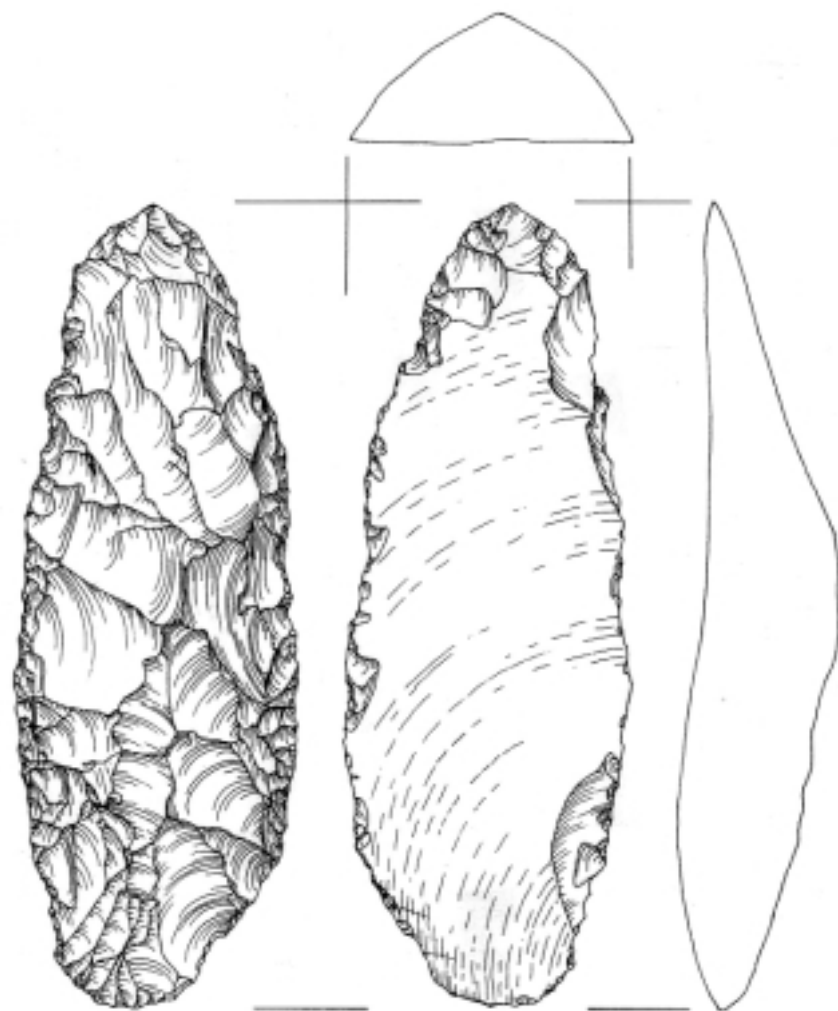


Illustration by Sara Moore

Thick, steep-edged tools like this one are often found in late ice age sites in the Noatak River basin and co-occur with damaged spear points. They show wear marks and damage that indicate use as woodworking tools, and they appear to be part of the tool kit used to manufacture and repair hunting weapons. This specimen is just over 4 inches (11 cm) long.

To understand this process, it is critical to have good information from Alaska—the gateway to the New World as it has been called—as a comparison with the early archeology of mid-latitudes.

The Caribou Crossing project in 2002, conducted by the cultural resources branch of the Western Arctic National Parklands, aimed to investigate both site-specific questions and contribute to some of these broader issues. As a federal agency, however, federal environmental policy and historic preservation laws, particularly the National Historic Preservation Act, were driving forces behind the work. Section 110 of this act directs federal agencies to identify and evaluate historic properties on their lands, and manage and maintain them so as to preserve their values. Furthermore, the National Park Service is unique among federal agencies in that a central part of its mission is to ensure important historic places and the information they hold are cared for and made available for public understanding and enjoyment. These laws and policies recognize that not only are sites valued by living people as links to their heritage and traditions, but are also important for their ability to provide information about history and past human behavior.

A logical first step toward managing the resources is to inventory and evaluate them, a tall order in the vast, remote, and rugged parks of Alaska. Many sites are already known. In the Brooks Range alone, 16.5 million acres of contiguous parklands (Kobuk Valley National Preserve, Noatak National Preserve, and Gates of the Arctic National Park and Preserve) contain more than 1,500 documented sites. To put this in

perspective, a recent study estimates only about one percent of the land area has been viewed by archeologists, perhaps another 85,000 sites remain undiscovered.

Threats to the resource are real, especially considering much of the archeological record in northern Alaska is largely a surface phenomenon. Due to slow sediment deposition in the region, tools discarded thousands of years ago are still visible on the ground and are thus vulnerable to erosion, breakage from animal trampling (easy to imagine for anyone who has seen the herds of several thousand caribou that migrate yearly through the Brooks Range), and dispersal due to frost heaving. Other impacts result from current human use. People may unknowingly (but nonetheless illegally) pick up an artifact as a souvenir, or may disassemble an ancient tent ring in order to weigh down a tarp. This is a difficult problem to quantify unless detailed base line information exists, since the absence of artifacts is impossible to detect. It is likely a serious one, given that modern park visitors are drawn to the same places that attracted past inhabitants of these lands—flat, well-drained ground, good viewpoints, and shelter from the wind.

For cultural resource managers, tackling this issue is a huge problem—how can we protect or even find all of the thousands of sites that exist? One way of prioritizing is to focus survey efforts in areas with the highest potential for impacts, such as popular access points or shorelines subject to intense erosion. Another key factor in setting work priorities is the information value of particular sites. Those most likely to have high quality information can be tar-

geted for more detailed documentation and protection. While seemingly self-evident, this is a challenge in northwestern Alaska where knowledge about the range of variation in sites and artifact types, and more importantly the causes of the variation, is still in a formative stage. While a site's ability to inform us about an interesting theme in human history or prehistory determines the significance of a site, themes are continually being redefined as we learn more about the archeology of the region. Thus we are presented with a moving target, and one we ourselves are responsible for clarifying.

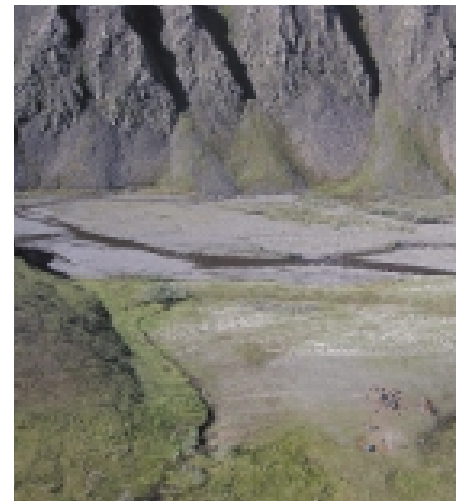
Another of our goals at Caribou Crossing in 2002 was to flesh out an emerging construct that NPS archeologists were examining as both a research and resource management tool: the Sluiceway Complex. This was a provisional term we had begun to use in reference to a handful of sites from the western Brooks Range, which contained the distinctive projectile points seen at Caribou Crossing. The term "complex" refers to a patterned set of artifact types or manufacturing techniques. It is an imprecise term that simply notes a set of traits that occur together and seem different from other phenomena archeologists have observed. It skirts the tough questions of whether the manufacturers of the tools shared common ideas or values (culture), spoke the same language, or even whether the artifacts date to the same period.

Until recently few sites in northwestern Alaska were dated to older than 9,000 years old, and before five years ago, there was no concept of a Sluiceway Complex or recognition of the artifact styles we were now discovering. Similar spear points had been

found as early as the 1960s, but their age and significance were ambiguous. No independent dating (from associated radiocarbon dates or stratigraphy) was available, and guesses based on the artifact shapes and styles varied from 2,000 years to 8,000 years old. Sometimes they were not even recognized as projectile points, but instead simply "bifaces", a general term without any functional or temporal implication.

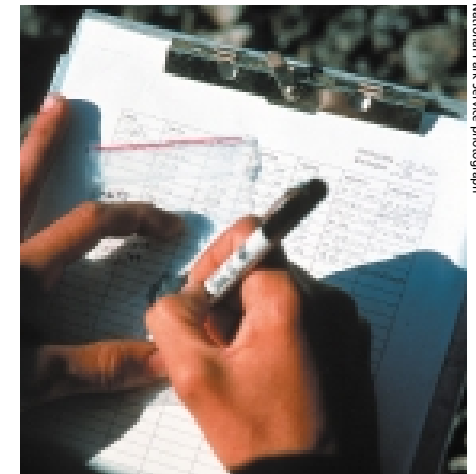
Identification of these tools began to change in 1993 when Western Arctic National Parklands archeologist Robert Gal and U.S. Geological Survey geologist Tom Hamilton discovered a site, later named the Irwin Sluiceway, in the Anisak River drainage, about 70 miles east of Caribou Crossing. Gal recognized the tools as projectile points since they had impact fractures—scalloped scars running down the face or edge of the point, which is a clear indication of a high velocity shock. He also knew these tools were not quite like anything previously noted in the region. The general outline of the points was not unique and could not be differentiated from tools 1,000 or 11,000 years old; however, manufacturing details were very distinctive. The flaking was quite regular, made in a serial fashion down each margin of the point. The edges along the base were ground or polished smooth—probably to help avoid damage to the wood or antler shafts to which the stone points were mounted. These features were reminiscent of early technologies known from the central Brooks Range and North Slope, as well as Paleoindian materials from the western U.S.

It was not until 1998 that an age for the



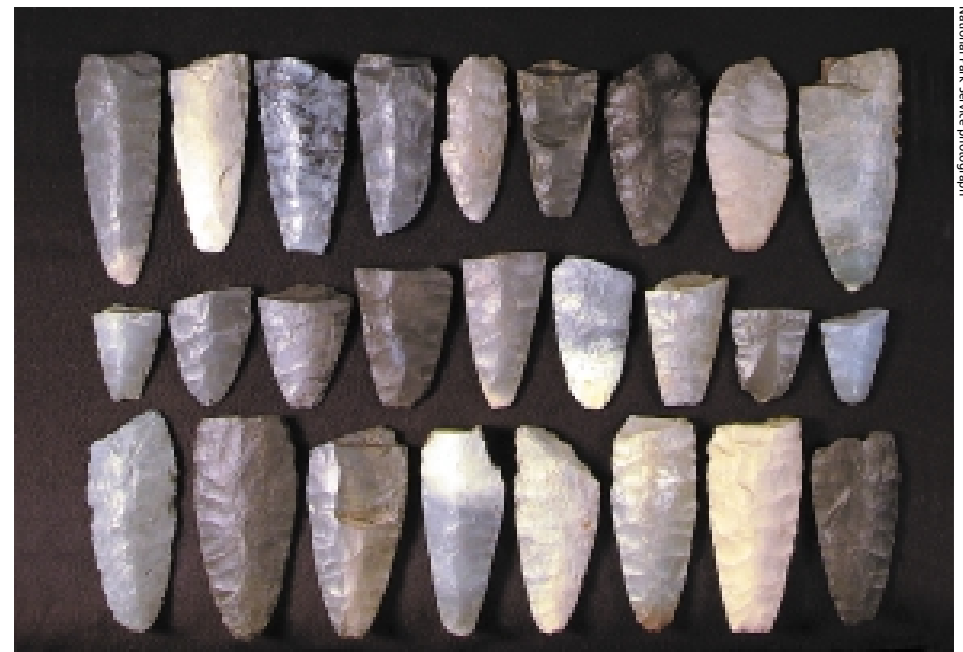
National Park Service photograph

Test excavations underway at the Caribou Crossing site in 2002.



National Park Service photograph

Archeologists catalog artifacts as they are collected and record precise location information for each item.



National Park Service photograph

A few of the 117 chert projectile points recovered during work at the Caribou Crossing site in 2002. Every single specimen was broken, and not one was a tip fragment. Instead, all are damaged basal portions that would have remained hafted in spear shafts. These were discarded at the site in the process of re-arming spears with serviceable points.